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AUTHOR Baroody, Arthur J.; Ginsburg, Herbert P.
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ABSTRACT

The study examined the effectiveness of a tutoring program on counting and number skills for trainable mentally retarded (TMR) and educable mentally retarded (EMR) students (5-14 years old). Experimental Ss received individualized instruction based on counting games while control Ss received instruction on objectives not related to counting. Analysis is presented of pre- and posttests on oral counting, counting transfer, counting by 10, enumeration and production of objects, enumeration transfer, production transfer, cardinality rule, subitizing, finger presentation of 1 to 10, order-irrelevance principle, and equivalence. Pretesting data suggested that basic counting skills cannot be taken for granted in retarded populations. The training was reasonably successful in extending Ss' oral counting sequence, suggesting that short-term intensive individual tutoring that focuses on count patterns is useful, perhaps especially with TMR pupils. Training was not generally successful in producing transfer. Findings suggested that if the S's cooperation can be obtained, oral counting training can be effective with mentally retarded children with relatively low mental ages. (CL)

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TMF and EMR Children's Ability to Learn Counting Skills and Principles

Arthur J. Baroody

and

Herbert P. Ginsburg

Graduate School of Education and Human Development

University of Rochester

Rochester, N.Y. 14627

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TMR and EMR Children's Ability to Learn

Counting Skills and Principles

PL 94-142 proposes that every mentally handicapped child has the right to an appropriate education. However, it is as yet unclear what constitutes an appropriate mathematics education for trainable and educable mentally retarded (TMR and EMR) children. In recent years, cognitive psychologists have made significant strides in our understanding of the mathematical development of normal IQ children. This study used a cognitive approach to examine the learning of basic counting and number skills or principle by TMR and EMR children to better define how these populations should be trained.

Many authorities (e.g., Hirshoren & Burton, 1979; Dunn, 1963) have argued that EMR pupils and TMR children, especially, are not capable of meaningful mathematical learning. On the other hand, recent research (e.g., Baroody & Snyder, 1983; Gelman, 1982; Spradlin, Cotter, Stevens & Friedman, 1974) has demonstrated that such children are capable of rule-governed as well as rote counting (i.e., oral counting beyond the first 12 to 20 rotely learned terms), enumerating objects (use of a one-one principle), the cardinality rule (the last count word uttered when enumerating a set represents the number of items in the set), the order-irrelevance principle (the order in which elements of a set are enumerated does not affect the cardinal designation of the set), and choosing the larger of N and N + 1 pairs (N + 1 N rule). Moreover, Gelman (1982) found that her subjects with mental ages (MA) greater than (but not less than) 4 1/2 years (implicitly) appreciated the stable-order principle (count words must be used in the same order for every count) as well as the one-one principle (one and only one count tag can be assigned to each item in a set), and the cardinality rule. This research attempted to extend previous efforts by directly examining the learning (including the transfer and retention) of basic counting skills. It also addressed such

issues as (a) whether or not there is a critical MA for such learning, (b) whether EMR and TMR really (implicitly) appreciate counting principles, and (c) if retardates can learn more "advanced" skills such as producing a specified number of objects or using fingers to automatically represent numbers (to make cardinal representations).

Method

Design

A total of 46 TMRs (IQ 33 to 50; CA 6 years & 0 months to 14-1) and 74 EMRs (IQ 51 to 78; CA 5-10 to 13-3) from 15 classes in two upstate New York BOCES districts were administered the counting and number pretest. From the subject pool, 26 TMR and 24 EMR children who could not successfully produce the count sequence to 40 were paired in terms of oral counting skills and—to the extent possible—the other pretest results and randomly assigned to an experimental or a control group. Both groups received a total of 11 hours of individualized instruction. Subjects were tutored 3 to 5 times a week, for 7 to 8 weeks. Experimental subjects received training on the counting/number skills for which they were deficient—largely through the use of counting games adapted from the Wynroth (1975) program. Token reinforcement procedures were avoided. Control subjects received instruction on IEP objectives not related to counting. Two EMR subjects were lost due to illness or behavioral problems. Subjects were individually retested immediately and again three and one half to four months after the training. Testers were blind to the subjects' group assignment.

Procedure

Oral counting. On two occassions (1 to 4 days apart), the child was first asked to count orally and, later, to count as the experimenter pointed at objects (stars affixed to 5 x 8 cards or candy). If the child stopped counting before 40, the tester prompted the child by asking what came next and then urged the child to continue. If the child maintained that s/he did not know, the tester supplied the unknown term. If the child

substituted an invented term for a decade (e.g., "twenty-ten" for thirty), jumped to decade term beyond thirty (e.g., "1...19, 60"), began repeating previously used segments (e.g., "1...19, 1, 2, 3"), or began to spew terms (e.g., "1...19, 16, 26, 80, 80"), the child was asked a check question (i.e., the child was asked what came after the last standard sequence term given). If the child did not then give a correct response to the check question, the tester supplied the correct term. The task was terminated before the child reached 40 if the child was obviously uncomfortable about continuing, after it was apparent the child had exhausted their standard sequence, or after the child was supplied two terms and s/he again errored.

Unassisted counts included terms the child spontaneously generated or was prompted to give. For each of the four counts, three unassisted counting scores were computed: (1) the highest standard sequence term achieved without assistance before any error was made ("unassisted high"); (2) "unassisted strings of four" score (1 point for each group of four standard sequence terms in the correct order; 0 to 10 points possible); (3) "unassisted correct terms to 40." The latter score was computed by awarding one point for each term between 1 and 40 mentioned—as long as the terms relative position was observed. For example, out of a possible 40 points each of the following responses would have been awarded 7 points: "1...7;" "1...6, 8" "1...9, 10, 40." One point instead of two, was given for two correct but reversed terms (e.g., 1, 2, 3, 5, 4, 6 = 5 points). One half a point was given for unique, consistent, specific substitutions that permitted the child to continue with the standard sequence (e.g., "fiveteen" for fifteen). No credit was given for incorrect substitutions (e.g., 1, 2, 3, 4, 9, 6... or ...12, 13, 14, 14, 16...). No point was given for a correct standard term that followed an incorrect insertion (e.g., each of the following responses would have been scored 3 points: "1, 2, 3, 9, 4;" "1; 2, 3, 9, 10, 4, 5;" "1, 2, 9, 10, 3, 4, 5").

Assisted counts included terms generated after the tester had given a check question or supplied a term as well as all spontaneous and prompted terms. For each

of the four counts, two assisted counting scores were computed: (1) "assisted strings of four" score (supplied terms and correct terms in response to a check question did not count toward a string of four) and (2) "assisted correct terms to 40." The latter was scored like unassisted correct terms to 40 except that terms after tester intervention were included and one half point was awarded for correct responses to check questions.

The best two of the four scores in each of the five score categories was averaged for the data analyses. Only the top two scores were used to better insure accurate measurement of competence.

Counting Transfer. Transfer was gauged by assessing the subjects' ability to generate the count sequence from 41 to 100. (The experimental training did not involve counting beyond 40.) A trial was administered on two different occassions. If a child did not get to 40 on his or her own effort, the tester asked: "What comes after 40 when we count?" A procedure similar to that for the basic counting task was followed—including the use of prompts and supplied terms. Unassisted and assisted counting were each scored in two ways: correct terms (0-60 points possible) and strings of four (0-15 points possible). Scoring was done in the same manner as described for the basic counting task.

Transfer was also gauged on the immediate and delayed post-test by requiring the children to use their mental number line to produce the number after a given N (e.g., "What follows '7, 8' when we count"). A total of 12 trials (four involved single digit responses; two, teens; four, two-digit; and two, decades). If a child responded incorrectly, the tester later readministered the trial. Two points were given for a correct response, and one point was given for a correct response on the second administration of the trial. Thus scores could range from 0-24 points.

Counting by tens. The tester explained, "Would you help "Cookie Monster" [a muppet] count his coupons. Each coupon is worth 10 cents, so let's count by tens to

find out how much Cookie Monster has. If the child remained silent, the tester commented, "If we count by tens, what comes after 10, 20...?" One point was scored for each correct decade between 30 and 100 (0 to 8 pts).

Enumeration and production of objects. The counting of a set of objects and the counting out of a specified number of objects from a quantity of objects was gauged in the context of a store game. There were a total of eight enumeration and eight production trials presented on two separate occasions. Half the trials for each task involved small quantities (2 to 5); half large (7 to 10). The tester introduced the task and first presented a practice enumeration and production trial: "Now we're going to play the store game. You can be the shopper, and I'll be the storekeeper. Here are some envelopes [the tester spread out three envelopes in front of the child]. How many envelopes are there? Let's count to see." If the child remained silent or made no attempt to use 1 - 1 counting, the experimenter said: "Count with me; this is one [pointing to an envelope]; now you keep going." If the child still did not count the set or use 1 - 1 counting, the tester finished demonstrating the counting procedure: "This is two [pointing to the next envelope], this is three [pointing to the last envelope]. Now you count them." If the child still did not respond or use 1 - 1 counting, the tester proceeded with the practice production trial: "You can take one envelope to use as a shopping bag. Take just one envelope." Then the enumeration and production test trials were administered in alternate order. Production trials were readministered if the child did not stop at the specified N or simply grabbed a bunch of objects.

The enumeration trials were scored according to the following criterion: 4 points for correct 1 - 1; 3 points for a tag error with correct 1 - 1 (e.g., ó ó ó ó), 2 points for a single partitioning or coordination error, 1 point for two errors (any combination of tagging, partitioning, or coordination errors), and 0 points for more than two errors or no 1 - 1 (see Gelman & Gallistel, 1978, for definitions of the error types). The enumeration of small and large sets were scored separately (0 to 16 possible points for each).

The production trials were scored according to the following criterion: 2 points for successfully producing the specified number of objects, 1 point if one or two minor errors were made (but a ! - 1 principle was observed) or if the child was successful when prompted to recount.

Enumeration Transfer. Transfer of the enumeration training was gauged in two ways on the posttests. First, on two occassions, subjects were given an extra large enumeration trial (18 blocks and 13 chips, respectively). The procedure and scoring for the trials was the same as that for the enumeration trials. Hence a child's total score could range from 0 to 8.

Second, on two occassions, a child was shown a number of objects and asked if the correct number of items had been presented. Specifically, in the context of a card game, the child was given 3 cards and asked if s/he had the correct number 3. Other comparisons were 7 cards where 8 was the correct number; 4 cards where 5 was correct, and 9 cards where 9 was correct. The child was also asked if a muppet ("Cookie Monster") took the right number of objects (5 sheets of paper where 4 was the correct amount, 8 dots where 8 was correct, 4 sheets of paper where 4 was correct, and 8 dots where 7 was correct). In each of the four small and four large number trials, two points were awarded if the child spontaneously made an effort to use 1-1 counting to check; 1 pointed if the child did so with prompting (e.g., "How can you find out if Cookie Monster took the right number of dots?" or "How do you know that you have the right number of cards"?). In either case, the child did not have to enumerate the set correctly to be awarded the point(s). "Skims" (child simply says number words as his/her glides over the array) or "flurries" (child simply points repeatedly at the array, but not in correspondence with the number words) were scored as unsuccessful responses (0 points). Two points were also awarded for each trial in which the child spontaneously responded appropriately; one if s/he responded appropriately with prompting ("Did Cookie Monster take the right number of dots; is he a good or bad

Cookie Monster"?) In either case, the child had to enumerate the set correctly and indicate that either the "correct" amount was present (e.g., "Yah he took four papers [as Cookie Monster should have]") or not (e.g., "No, bad Cookie Monster," "He took too many," or "He needs more"). Thus for each trial, a score of 0 to 4 was possible, for both the small and large number tasks, a total score of 0 to 16 was possible.

Production Transfer. Transfer of the production training was gauged in two ways on the posttests. First, on two occassions, an extra large production trial was administered (12 and 16, respectively.) (Training did not involve sets of more than 10.) The transfer items were administered and scored in the same manner as the production trials. Thus, a total score of 0 to 4 points was possible for each of the small and large number tasks.

Second, on two occassions, the child was asked to create sets in ways that modeled every day situations. In the context of a card game, the child was asked to give him/herself or the tester a specified number of cards. The child was also instructed to take a specified number of objects (paper or dots) as prizes for himself/herself or a muppet. In all, there were six small and six large number trials. For each trial, a spontaneous effort to use 1-1 counting to produce the required set was scored as 1 point. The child did not have to produce the correct number of items to receive this point. For example, if a child spontaneously started to count out objects but did not stop at the specified value or became distracted and stopped the counting too early, one point was awarded. An additional point was awarded if the child made only a minor 1-1 error (e.g., counted out the right number but then included an extra item, left out a number tag, failed to tag an item), and an additional two points was awarded if the child produced the correct number of items. Thus the score for each trial could range from 0 to 3, the total small or large task score could range from 0 to 18.

Cardinality Rule. The cardinality rule was evaluated with four small number trials and four large number trials. Sets of 1, 4, 7 and 10 were administered in random order on the first occassion; sets of 3, 5, 8 and 9 on the second. The tester instructed, "Now we're going to play the 'Hidden Stars' game. Count these stars out loud." The tester presented the practice trial consisting of two stars and then continued: "When you're done, I'll cover them, and you tell me how many stars I'm hiding." The tester then encouraged the child to count the array, covered the array and asked, "How many stars am I hiding"? If the child did not respond, did not respect the 1 - 1 principle, or gave a tag other than the last tag generated in his/her count, the tester modelled the correct procedure. The tester used his/her finger to count the stars ("one, two,") and commented, "So there are two stars." The tester then turned the card over and asked: "How many stars am I hiding? If the child did not respond or responded incorrectly, the tester said, "I think I counted two stars. Let's see [tester turned the card over], Yes, one, two." The experimental trials were then administered. A trial was scored as correct if a child applied the rule regardless of enumeration correctness. If a child simply repeated his/her count sequence in response to the how many question, the trial was scored as incorrect. The child was scored on the number of small and large number trials separately (0-4 correct possible for each).

Subitizing. Automatic recognition of die patterns three, four, five and six were evaluated twice on two occasions for a total of sixteen trials. The tester explained: "Let's play the 'Race Game'." Do you want to be the cowboy or indian? O.K. Let's put our men here at the starting line. I'll roll this to see how many spaces your [figurine] can move, [the tester manipulated a die so that the first practice trial showed: 2 dots]. How many is that?" The tester then instructed or helped the child move his/her figurine two spaces. The tester then manipulated the die so that the second practice trial showed (one dot) and the same procedure as above was repeated. Then, in random order, the experimental trials were presented (the same number was

not presented twice in a row). The criterion for automatic recognition was a correct label for the die pattern in 3 seconds or less, without counting. A child was considered able to recognize a number pattern if s/he was correct for the pattern at least 3 of 4 times. A child's score was the number of die patterns s/he could recognize (0 to 4 possible).

Finger representation of 1 to 10. An ability to hold up a specified number of fingers was evaluated in a "Finger Game." A total of 8 small number and 8 large number trials were administered on two occasions. The child was instructed: "Now we're going to play the 'Finger Game'. Show me one finger." If necessary, the tester added: "Hold up one finger." If the child still did not respond, the tester said, "Let me show you one finger (tester held up first finger of left hand). Now you hold up one finger." The tester helped the child if necessary. Then in random order the small number (2, 3, 4, 5) and large number (7, 8, 9, 10) trials were given. The same trials were presented during a second session. To be successful, a child had to display automatically (within about 3 seconds) a cardinal representation of the number. Unsuccessful responses included counting out the specified number of fingers, slowly showing the fingers, and an inability to represent the number with fingers.

Order-irrelevance Principle. On two occasions, two small and two large number trials were used to gauge a child's appreciation that starting point and the order of a count did not affect the cardinal designation of a set. For each trial, the child was asked to count a set of blocks. For half the small and large number trials, the tester then pointed to the last item enumerated and asked: "We got N counting this way [the tester indicated the direction of the subject's count]; what do you think we would get if we started here [tester pointed to the end-item] and counted the other way [the tester indicated the opposite direction and covered the array to prevent further counting]"? For the other half of the small and large number trials, the tester pointed to the mid-item, after the child's initial count and asked: "We got N counting this way;

what do you think we would get if we started here [tester pointed to the mid-item] and counted all the blocks [tester made a sweeping motion over the whole set and covered the set to prevent further counting]"? Interspersed among the experimental trials were check trials to prevent or detect a response bias. In the check trials, the tester added one block and said: "You counted N blocks; I'll add one more; how much is N and one more altogether?" The number of correct responses to the small and large number trials were tallied (0 to 4 points possible for each).

Equivalence. A total of four small number trials and four large number trials involving matching a set from a sample were administered over two sessions. On each occasion, the child was first administered two practice trials (sample = 1: choices = 2, 1, 3 and 2: 1, 3, 2). The child was told: Let's play the "Cat (Dog) Game." "Look at this cat (dog)—see how many balls it has (the tester pointed to the sample of the first practice array). Can you find a cat (dog) down here that has the same number of balls as this cat (dog)?" If the child was correct, the tester commented: "That's good, this cat (dog) up here has one, and this cat (dog) down here has one." If the child was incorrect, the experimenter explained, "This cat (dog) up here has one ball, this cat (dog) down here has one." The second practice trial was then administered in the same way. The experimental trials were administered in an identical manner, except that no feedback (correction) was provided. The experimental trials on the first occasion were administered in the following order: 4: 4, 3, 5; 3: 4, 5, 3; 8: 10, 6, 8; and 10: 11, 10, 9. The trials on the second occasion were 4: 5, 4, 3; 5: 3, 7, 5; 7: 7, 9, 8; and 9: 10, 8, 9. Success was defined as 3 or 4 correct matches for both the small and large number task.

Results and Discussion

A report of the results and their educational and theoretical implications are described in two sections: (1) Ability Data and (2) Training Results. The first section focuses largely on the pretest results. The second section focuses on the difference (gain) data and evaluates the effectiveness of the experimental training.

Ability Data

On the pretest, an ability to generate the count sequence varied greatly within the subject pool and in many ways paralleled that of young normal IQ children (see Table 1). With the exception of one child who used letters on occasion, the subjects used only numbers in their oral counts and thus clearly distinguished between counting and noncounting words (cf. Fuson, Richards, & Briars, 1982). The subjects occasionally exhibited rule-governed errors such as substituting "twenty-ten" for 30. This is consistent with earlier research (Baroody & Snyder, 1983) that indicated that implicit rules underlie count sequence production in mentally retarded as well as normal IQ children. Thus, except for the first portion of the sequence, it may be that counting need not be taught in a rote fashion to the mentally retarded. In other words, it may be useful to exploit the structure of the number sequence in teaching even low functioning children to count. Moreover, errors such as substituting "five-teen" for fifteen, or "tenny-teen" for twenty should be taken as encouraging signs, for they suggest recognition of a number sequence pattern.

The count sequences of some subjects consisted of an initial conventional portion, followed by a stable nonconventional segment and a final nonstable nonconventional "spew" (cf. Fuson & Hall, 1983). Many subjects, however, did not appear to have a stable nonconventional portion and simply spewed or repeated previously used portions after exhausting their standard sequence. Fuson et al. (1982) argue that the production of spews is inconsistent with a stable-order principle (cf. Gelman, 1982; Gelman & Gallistel, 1978). Moreover, the repetition of terms in nonconventional segments by many subjects would seem inconsistent with not only a stable-order principle but a "uniqueness scheme" (an appreciation for the need to generate a sequence of distinct terms) (cf. Baroody & Price, 1983). These results are consistent with data on normal IQ children that suggest that a stable-order principle and a uniqueness scheme may be relatively sophisticated counting notions (Baroody &

Price, 1983). Thus it may be helpful to provide mentally retarded children explicit guidelines concerning these counting principles (e.g., "When we count things, we must make sure to use a new number for each thing we point to").

On the other hand, it should be noted that these counting principles are very difficult to evaluate. That is, some of the subjects may have implicitly appreciated the need for a stably ordered, unique number sequence but, because of the demands of the task (e.g., the tester's prompt to give the next number), the child may have responded incorrectly in order to continue and thus please the tester. Moreover, under some circumstances a spew or a repeated term is <u>not</u> necessarily inconsistent with knowledge of a stable-order principle or a uniqueness scheme. A child might implicitly appreciate that numbers should have a particular order and that each term should be distinct, but performance factors may limit their ability to observe these principles when they count. For example, a child may exhaust his standard sequence and not remember what s/he had previously said in such a situation. As a result, the child may choose different nonstandard terms on different occasions. However—on each occasion to count—if the child appreciates the stable-order principle, s/he will avoid repeating standard or nonstandard terms (that s/he remembers using). Thus a spew or repeated term per se is not inconsistent with a stable-order principle. It is essential to investigate the nature and reason for a children's spews or repeated terms in order to pass judgment on their knowledge of their count principles. Needed to investigate stable-order and uniqueness principles are careful case studies or studies in which the child evaluates performances that violate these principles.

The testing also shed some light on the "decade problem"—i.e., how children learn the correct order of the decades so as to count to 100 by ones. Fuson et al. (1982) outline three hypotheses concerning how children solve the decade problem: (1) Children can learn the decades rotely as end items for each series; (2) they can learn the decade (count by tens) by rote and use it to fill in the count by ones sequence, or

(3) they can learn that the decades are a modified version of the original 1-9 sequence and use this knowledge to fill in the ones count. This last hypothesis was illustrated by one EMR subject who would get to the end of a series (e.g., "...58, 59") and then used her original sequence to figure out the next decade (e.g., "1, 2, 3, 4, 5; 6—ah six-ty"). This procedure was repeated until she got to 100. Other data at least partially support the first hypothesis. Some subjects could not count by tens but were able to count up to 30 (or even 39) but not further. That is, they learned 30 as the end item for the proceeding series ("...28, 29, 30") and some were able to continue until they got to the next decade (40), which they had not memorized. In brief, it may be that some children must rotely learn some of the decades before they see the pattern/rule for generating the decades ("use the original sequence 1-9 but add -ty"). Thus, for some children, a combination of hypothesis 1 (or 2) and 3 may be applicable. How mentally retarded (and normal IQ) children solve the decade problem clearly needs further study (cf. Fuson et al., 1982).

Gelman and Gallistel (1978) note that coordinating the skills of generating an oral count and pointing to each item in an array may be especially difficult for preschoolers when trying to start or end the enumeration process. While there is some question as to whether or not normal IQ preschoolers typically make "coordination errors" (Fuson & Mierkiewicz, 1980), such errors (e.g., not tagging the first or last item or continuing the number after pointing to the last item) were common in this TMR/EMR sample. Nevertheless, most of the EMR and TMR subjects could effectively enumerate small sets (see Table 1), and nearly all made an effort to use a one-one scheme with at least small number trials. There was little evidence of a "list exhaustion" scheme (a tendency not to stop the count sequence after the last item of a set had been tagged), which Wagner and Walters (1982) claim precedes a one-one scheme. That is, there was clear evidence that even severely retarded children can learn a "stop rule" (stop the count sequence after the last item of a set is tagged),

which Wagner and Walters argue develops relatively late. However, longitudinal research with (mentally retarded) children who initially have no enumeration ability is needed in order to adequately test Wagner and Walter's hypothesis that a list exhaustion scheme necessarily precedes a one-one principle developmentally.

Moreover, most (but not all) appreciated the cardinality rule—the special status of the last count words in the enumeration process. However, use of the cardinality rule does not necessarily imply a deep appreciation of cardinality. It may simply indicate that a child has learned to respond to the "How many?" question with the last tag generated in the enumeration process (Fuson & Hall, 1983; von Glaserfeld, 1982). This argument is supported by the observation that a number of subjects, despite little or no effort to use the correct count sequence or 1-1 counting, nevertheless, responded correctly to the cardinality rule task. For example, given 15 stars one boy counted: "1...5, 19, 14, 12, 10, 9, 20, 49, 1, 2, 3." In response to the tester's question of how many stars there were, he responded: "3." Given a set of 10, another boy announced "1, 2, 3, 4 as his finger skimmed over the set; given a set of 7 and 15, he reacted the same way, announcing "1...6" and "1...11," respectively. In each case, he responded to the cardinality question correctly.

Unlike Gelman's (1982) study, however, our results did not indicate that a mental age of 4 1/2 has special significance. Gelman found that below this MA, her subjects showed no sign of stable-order, one-one or cardinality principles. We analyzed the pretest results of 13 subjects who were included in the training study (as either experimental or control subjects). The results are summarized in Table 2. Nine of these subjects exhibited no consistency in the terms they chose after exhausting their standard sequence (scored No in Column 5 of Table 2) , and four exhibited only some consistency (scored Weak in Column 5 of Table 2). Moreover, only two children tended to avoid repeating previously used (and easily remembered) terms (e.g., beginning with 1, 2, 3... again, repeating the same term successively, repeating one or more of the

terms 1 to 9). One of these children did not repeat a previously used terms until he got to the thirties (1...34, 35, 34, 40...), and he repeated a term on only one of four trials. Because 11 of 13 children tended to spew and repeat terms that they should have remembered using, it appeared that most subjects with a MA of less than 4 1/2 years did not appreciate the stable-order principle. However, because of the relative difficulty of the principle or difficulties in measuring the principle, these results are not greatly different than those with mentally retarded children of a greater MA (or normal IQ children of an equal MA).

No direct evidence was collected on a 1-1 principle. Nevertheless, seven children enumerated 1 to 5 objects with 100% accuracy, two made only a single minor enumeration error, and the rest (4) enumerated at least half the sets correctly. These data suggest that mentally retarded children with very young mental ages can learn to count objects in a manner consistent with a one-one principle. Moreover, 9 of the 13 consistently used the cardinality rule with small sets (i.e, were correct on at least 3 of 4 trials). While use of the cardinality rule in itself does not imply a very deep understanding of cardinality, other evidence suggests that at least a few of these children appreciated the cardinality principle in a meaningful sense. Five were successful on the order-irrelevance task. That is, they appeared to appreciate that order in which elements of a set are enumerated in does not affect the outcome (the cardinal designation of a set). Moreover, seven were able to automatically represented 2 to 5 on their fingers on at least half the trials. This indicated that they automatically associated a cardinal term with a particular display of fingers (concrete cardinal representation). Finally, three children could correct on one half or more of the small number production trials. That is, they could, with some consistency, register a cardinal term and count out objects until they reached the target. This indicates that they mastered what Fuson and Hall (1983) term the cardinal-count transition, a somewhat more sophisticated cardinal notion than the cardinality rule. In

sum, there was a range of evidence to indicate that at least some mentally retarded with in MA of less than 4 1/2 appreciated both the one-one and cardinality principles. The difference between our results and Gelman's may possibly be due to the academic emphasis of our subjects' school programs.

Consistent with earlier findings (Baroody & Snyder, 1983; Spradlin et al., 1974) producing a specified number of objects was a relatively difficult task. For example, a number of subjects would begin counting out objects but did not stop after reaching the specified amount. This has been attributed to a failure to remember the goal of the task (see Resnick & Ford, 1981). Specifically, "no-stop errors" may be due to a failure to register or to forgetting the specified amount (registered-deficit hypothesis). Another possibility is that the child registers (and can later recall) the specified number but, because the counting process so taxes working memory, the child fails to match the specified N to the N in the count sequence (matching-deficit hypothesis).

In addition to no-stop errors made by many subjects, we observed another interesting production error. Asked to count out a set (N), the child would produce the incorrect number of items but would label the last item with the specified N. One TMR boy often made a no-stop error but sometimes ended his count with the correct tag. For example, asked to give the tester seven play dollars, he responded by counting out objects with the following tags: "1, 2, 3, 4, 5, 6, 7, 8, 9, 7." That is, the child failed to stop when seven items had been counted out, but appeared to remember the goal ("get seven items) and so tagged the last item in the pile "seven." Another TMR boy regularly made this "end-with-N" error but usually after abbreviating his count. For example, in response to count out seven dollars, he counted: "1, 2, 3, 4, 7".

Note that, because these subjects (repeatedly) ended their production process with the "correct" tag, an end-with-N error cannot be reconciled with a register-deficit hypothesis. This error is not inconsistent with a matching failure hypothesis.

In the first example, the child is unable to simultaneously count and match and so fails to make the match. However, with the last item—freed of the demands of the counting process—he was again able to recall (focus on) the goal of the task and so labeled the item "seven." In the second example, the child may have dealt with the overload on working memory posed by simultaneously counting and remembering the goal by abbreviating the counting process. That is, the child skipped to the target tag (N) so as not to forget it. This may account for a number of subjects who could correctly produce small sets of say 2 or 3 but made an end-with-N error with larger sets. Alternatively, these "inconsistent" subjects may have simply been trying to minimize their effort on the more demanding large production trials. That is, to avoid work they merely gave the appearance of performing the task and then end the N the tester had requested. Because the two TMR boys described above were unable to produce either small or large sets and because their solutions to the small number trials did not save them effort, it does not seem that their end-with-N errors were merely the result of a performance failure (a Type II error).

Though the matching-deficit hypothesis might account for the end-with-N errors of the two TMR boys described above, we believe that another explanation (a conceptual-deficit hypothesis) is plausible. It may be that these two mentally retarded subjects had not achieved a very sophisticated understanding of cardinality. More specifically, it may be that these children remembered the specified amount but, because of an inability to make what Fuson and Hall (1983) the "cardinal-count transition" (appreciate that the cardinal term 5 can represent the same thing as the 5 in the count sequence), they have no basis for even attempting to make a match.

Briefly, the pretest results also indicated that an order-irrelevance principle, the use of fingers to represent 6 to 10, automatic recognition of number patterns and determining the equivalence of larger sets were relatively difficult tasks for TMR and even EMR children (cf. Baroody & Snyder, 1983; Spradlin et al., 1974) (see Table 1).

Again, however, there was a very wide range in performance. For example, a few EMR children even exhibited elementary reasoning ability on the equivalence task. After determining the amount of the sample set, several subjects counted the first and the second non-matching choices and then—without counting the last choice—correctly concluded that the last choice was the match.

Like Gelman's study (1982) this evidence suggests that basic counting skills cannot be taken for granted in retarded populations. Unlike most normal IQ children who acquire informal skills spontaneously through everyday experiences, many retarded children may need remediation of such basic skills as generating the count sequence, enumerating objects, and a cardinality rule—not to mention more sophisticated skills such as producing a specified amount or establishing the equivalence or nonequivalence of two sets. Unlike Gelman's results, however, a mental age of 4 1/2 did not appear to be critical for learning these skills. Thus these results do not support the conclusion that counting training or experience would be useless for retardates with an MA less than 4 1/2. Indeed, one of the most striking characteristics of the pretest data was the wide variation in abilities within what might be thought of as relatively homogeneous groups—even within the elementary level (6-to 10-year-old) TMR children. In brief, the results underscore the argument that general labels are not useful for educational planning and that diagnosis needs to focus on individual assessment of specific skills (e.g., Baroody & Ginsburg, 1982; Ginsburg & Baroody, 1983).

Training Results

The training was reasonably successful in extending the TMR and EMR subjects' oral counting sequence. The TMR experimental subjects improved at a statistically significant level on four of the five counting scores on the immediate posttest and on all five counting scores on the delayed posttest (see Table 3, lines 1-5). Indeed, the TMR experimental subjects not only tended to retain their gains better than their

control counterparts but some appeared to continue to improve after the training, rather than lose ground between the posttests. The EMR experimental subjects improved at a statistically significant level on all five immediate posttest counting scores, but they retained a statistically significant advantage on only two delayed posttest scores (see Table 4, lines 1-5). The gains by both experimental groups was accomplished despite the fact that the control subjects continue to receive their routine mathematics instruction, which typically included oral counting. The better performance by the TMR experimentals might be attributed to their somewhat larger sample size, older age, and/or greater reliance on individualized instruction. Moreover, because of the limited pool of EMR children available, several EMR subjects were included that were scored in the screening as borderline in cooperativeness. In brief, the results suggest that, in general, short-term, intensive individual tutoring that focuses on count patterns is useful even, perhaps especially, with TMR pupils.

While the TMR and EMR experimental subjects outperformed the control subjects on the counting transfer tasks, the differences did not reach statistical significance (see Tables 3 and 4, lines 6-10). Thus, while an analysis of individual cases indicated that a few TMR and EMR experimental subjects appeared to generalize their learning, the training was not generally successful in producing transfer. The data did indicate that while some subjects were still in what Fuson et al. (1982) call the acquisition phase of oral counting development, many were in the more advanced elaboration phase. That is, some subjects could not produce interior terms independently. Many though could produce contiguous terms without producing the whole sequence. Moreover some of these subjects could even use the count sequence to solve mentally simple addition problems. Thus it appears that even TMR children can learn applications for their oral count sequence, if given enough time and experience.

Four of the TMR experimental subjects made impressive gains in their ability to count by tens. Unfortunately, this was not enough to produce a statistically significant difference (see Table 3, line 11). Almost half (5) of the EMR experimental subjects improved their count by ten skill—almost enough to produce statistically significant results on the immediate posttest (see Table 4, line 11).

While enumeration training with larger sets (6 to 10 objects) was not successful with TMR children, it had some success in promoting learning and transfer with EMR subjects (see lines 12-15, Tables 3 & 4, respectively). The training was apparently of insufficient duration to have an impact on the production of larger sets or its transfer for either TMR or EMR children (see lines 16-19). This is consistent with previous research that has shown that the production task is an especially difficult one for mentally retarded populations. Nevertheless, the fact that some EMR and TMR could successfully produce up to 20 items suggests that, given sufficient training, this skill can be mastered by these populations.

There was some evidence of incidental learning (cf. Ross, 1970). A number of TMR experimental subjects learned to recognize at least a few of the number patterns on the dice used in some of the training activities, but the gain was not retained (see Table 3, line 20). A number of EMR experimental subjects also made significant improvement, but the difference did not reach statistical significance on either posttest.

Unlike the TMR group, EMR experimental subjects showed some improvement in their ability to represent numbers 6 to 10 on their fingers (see lines 21 in Tables 3 & 4). Unfortunately, the gain was not retained on the delayed posttest. (Training was hampered in a number of cases because subjects had previously learned to "sign" numbers. This strongly interfered with their learning to use their fingers to make either ordinal (sequential) or cardinal representations of numbers.) Both automatic recognition of die patterns and automatic cardinal representations with the fingers

may be important means for facilitating the development of more economical addition strategies later (see, e.g., Baroody & Gannon, 1983; Bley & Thornton, 1981).

Finally, the training did not result in learning the order-irrelevance principle or a better appreciation of equivalence (lines 22, 23, and 24 in Tables 3 & 4). Again, the training may simply not have been of sufficient duration. Because some subjects were competent in these areas, it appears that these concepts are learnable by these populations.

To address the issue of whether or not there might be a critical level of development for training mentally retarded children, the experimental subjects' oral counting training results were analyzed in terms of mental age (2 - 11 to 6 - 7), IQ (33 to 71), and chronological age (7 - 1 to 16 - 5). As can be seen in Table 5, these factors were not significantly related to the various counting (gain) scores on Posttests 1 and 2. Moreover, the children with the lowest MA (less than 4 1/2) did not learn at a significantly less significant level than did children with a greater MA (see Table 6). Thus, it appears that, if the child's cooperation can be obtained, oral counting training can be effective with mentally retarded children with relatively low mental ages.

In conclusion, the results on the oral counting training, at least, suggest that individualized instruction that does not rely on token reinforcement can produce learning and retention in EMR and even TMR children. Transfer was not demonstrated but this may have been due, in part, to the brevity of the intervention and the inadequacy of the transfer measures. Success of the oral counting did not appear to be dependent upon mental age—at least for the range included in this study. Clearly, much research still needs to be done to explore the learning of basic counting and number skills and principle by the mentally retarded.

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Table 1

Performance of Study 1 TMR and EMR Subjects on the Pretest[1]

	TMR (N = 26)			EMR (N = 24)		
	Competent	Weak	Deficient	Competent	Weak	Deficient
Count 1-13	62%	23%	15%	67%	12%	12%
14-19	42%	35%	23%	37%	21%	42%
20-29	31%	19%	50%	25%	17%	58%
30-40	0%	27%	73%	0%	25%	75%
Count by tens 10-40	19%	27%	54%	25%	12%	62%
Count by tens 50-100	4%	12%	85%	4%	21%	75%
Enumeration 1-5	65%	35%	0%	54%	46%	0%
Enumeration 6-10	27%	38%	35%	29%	25%	46%
Production 1-5	38%	15%	46%	46%	29%	25%
Production 6-10	19%	23%	58%	29%	21%	50%
Fingers 1-5	46%	31%	19%	67%	21%	12%
Fingers 6-10	12%	4%	85%	12%	21%	67%
Equivalence 1-5	15%	38%	46%	25%	37%	37%
Equivalence 6-10	8%	15%	77%	12%	25%	12%

For count by ones, count by tens, and finger representations of numbers:

competent = all items correct;
weak = 1 or 2 errors;
deficient = 3 or more errors.

For enumeration, production, and equivalence:

competent = 76% or more of the trials correct;
weak = 26 to 75% of the trials correct;
deficient = 0 to 25% of the trials correct.

[1] Does not include data of subjects who were excluded from Study 1 either because their skills were too advanced or because their behavior or multiple handicaps precluded valid testing.

Table 3

TMR Training Results

Skill	Item	Immediate Posttest N (pairs compared)	Immediate Posttest Mean (gain) Experimentals	Immediate Posttest Mean (gain) Controls	Immediate Posttest Mean Difference	Delayed Posttest N (pairs compared)	Delayed Posttest Mean (gain) Experimentals	Delayed Posttest Mean (gain) Controls	Delayed Posttest Mean Difference
Counting	1. Unassisted high [0 to 40]	13	+6.2	+2.2	4.0*	12[a]	+7.2	-0.2	7.4**
	2. Unassisted correct terms to 40 [0 to 40]	13	+6.2	+2.4	3.8*	12[a]	+8.8	+1.5	7.3**
	3. Unassisted strings of four [0 to 10]	13	+1.6	+0.8	0.7*	12[a]	+2.1	+0.3	1.7**
	4. Assisted correct terms to 40 [0 to 40]	12[a]	+8.0	+3.0	5.0*	11[a]	+7.7	+1.3	6.4**
	5. Assisted strings of four [0 to 10]	11[a]	+1.8	+1.0	0.8[b]	12[a]	+1.7	+0.4	1.3**
Counting Transfer	6. Unassisted correct terms: 41-100 [0 to 60]	13	+4.6	+1.9	2.7	13	+3.5	+2.8	0.6
	7. Unassisted strings of four: 41-100 [0 to 15]	13	+1.1	+0.3	0.8	13	+0.8	+0.5	0.2
	8. Assisted correct terms: 41-100 [0 to 60]	13	+10.7	+7.8	2.8	13	+9.9	+9.1	0.8
	9. Assisted strings of four: 41-100 [0 to 15]	13	+2.4	+1.6	0.8	13	+1.9	+1.7	0.2
	10. Number after given N [0 to 24]	13	13.2	11.3	1.8	13	14.9	12.1	2.8[b]
Skip Counting	11. Count by tens: 30 to 100 [0 to 8]	12	+1.2	+0.2	0.9	12	+2.0	+0.5	1.5[b]
Object Counting	12. Enumeration: Sets 6-10 [0 to 16]	10	+0.9	+0.9	0	8	+2.5	+4.1	-1.6
Object Counting Transfer	13. Enumeration: Sets 11-20 [0 to 8]	10	1.8	2.9	-0.9	10	3.1	1.9	1.2
	14. Application: Sets 6-10 [0 to 16]	10	3.8	2.7	1.1	10	4.5	5.1	-0.6
Counting Out a Set	15. Production: Sets 1-5 [0 to 8]	7	+1.4	+2.0	-0.6	7	+1.4	+2.4	-1.0
	16. Production: Sets 6-10 [0 to 8]	10	+0.3	+0.4	-0.1	9	+0.4	+0.4	0
Counting Out a Set Transfer	17. Production: Sets 11-20 [0 to 4]	10	0.2	0.7	-0.5	10	0.7	0.9	-0.2
	18. Application: Sets 1-5 [0 to 18]	8	6.5	8.2	-1.7	8	7.6	8.1	-0.5
	19. Application: Sets 6-10 [0 to 18]	10	5.6	4.3	1.3	10	7.2	6.6	0.6
Subitizing	20. Recognition of die patterns 3 to 6 [0 to 4]	12	+0.5	-0.1	0.6*	12	+0.2	+0.2	-0.1
Shows N Fingers	21. Automatically represents 6-10 [0 to 5]	10	-0.4	0	-0.4	10	-0.7	+0.1	-0.8
Count Principle	22. Order-irrelevance principle [0 to 2]	10	0	-0.1	0.1	-	-	-	-
Equivalence	23. Matching sets 3 to 5 [0 to 8]	8	0	0	0	-	-	-	-
	24. Matching sets 6 to 10 [0 to 8]	11	0	+0.1	-0.1	-	-	-	-

[a]Because of ceiling effects, one or two pairs were considered to have a difference score of zero and not included in the analysis.

[b]Difference tended toward significance: $p < .10$ (Wilcoxon Signed Ranks Test).

*$p < .05$. **$p < .01$ (Wilcoxon Signed Ranks Test).

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Table 4

EMR Training Results

Skill	Item	N (pairs compared)	Mean (gain) Experimentals	Mean (gain) Controls	Mean Difference	N (pairs compared)	Mean (gain) Experimentals	Mean (gain) Controls	Mean Difference
Counting	1. Unassisted high [0 to 40]	10[a]	+11.2	+0.7	10.5*	9[a]	+13.6	+2.3	11.3*
	2. Unassisted correct terms to 40 [0 to 40]	10[a]	+7.6	+4.1	3.5*	9[a]	+7.4	+5.7	1.7
	3. Unassisted strings of four [0 to 10]	10[a]	+2.5	+0.5	1.9*	9[a]	+2.2	+0.9	1.3[b]
	4. Assisted correct terms to 40 [0 to 40]	11	+8.7	+4.0	4.7**	10[a]	+7.4	+4.5	2.9
	5. Assisted strings of four [0 to 10]	11	+2.6	+0.6	2.0**	10[a]	+2.2	+0.8	1.4*
Counting Transfer	6. Unassisted correct terms: 41-100 [0 to 60]	11	+5.8	+1.5	4.4	11	+9.4	+4.9	4.4
	7. Unassisted strings of four: 41-100 [0 to 15]	11	+1.5	+0.5	1.0	11	+2.0	+1.2	0.8
	8. Assisted correct terms: 41-100 [0 to 60]	11	+10.6	+7.5	3.1	11	+13.5	+9.4	4.1
	9. Assisted strings of four: 41-100 [0 to 15]	11	+2.8	+1.9	0.9	11	+3.2	+2.1	1.1
	10. Number after given N [0 to 24]	11	13.1	11.1	2.0	11	14.4	13.7	0.6
Skip Counting	11. Count by tens: 30 to 100 [0 to 8]	9	+2.6	+0.2	2.3[b]	9	+2.1	+1.0	1.1
Object Counting	12. Enumeration: Sets 6-10 [0 to 16]	8	+3.1	0	3.1*	6[a]	+2.5	+1.5	1.0
Object Counting Transfer	13. Enumeration: Sets 11-20 [0 to 8]	8	3.5	1.6	1.9[b]	8	4.7	2.1	2.6*
	14. Application: Sets 6-10 [0 to 16]	8	7.5	4.1	3.4*	8	7.7	5.1	2.6
Counting Out a Set	15. Production: Sets 1-5 [0 to 8]	4	+1.5	+0.2	1.2	3[a]	+1.7	+1.7	0
	16. Production: Sets 6-10 [0 to 8]	7	+1.1	+0.9	0.3	6[a]	+1.0	+0.5	0.5
Counting Out a Set Transfer	17. Production: Sets 11-20 [0 to 4]	7	1.0	0.1	0.9	7	1.3	0.3	1.0
	18. Application: Sets 1-5 [0 to 18]	4	5.2	8.0	-2.7	4	5.2	6.5	-1.2
	19. Application: Sets 6-10 [0 to 18]	7	7.4	5.6	1.9	7	8.6	5.0	3.6*
Subitizing	20. Recognition of die patterns 3 to 6 [0 to 4]	8	+0.9	+0.2	0.6	8	+0.7	+0.5	0.2
Shows N Fingers	21. Automatically represents 6-10 [0 to 5]	8	+1.1	+0.2	0.9[b]	8	+0.8	+0.4	0.5
Count Principle	22. Order-irrelevance principle [0 to 2]	9	+0.2	+0.4	-0.2	-	-	-	-
Equivalence	23. Matching sets 3 to 5 [0 to 8]	3	0	0	0	-	-	-	-
	24. Matching sets 6 to 10	6	0	0	0	-	-	-	-

[a]Because of ceiling effects, one or two pairs were considered to have a difference score of zero and not included in the analysis.

[b]Difference tended toward significance: $p < .10$ (Wilcoxon Signed Ranks Test).

*$p < .05$. **$p < .01$ (Wilcoxon Signed Ranks Test).

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Table 5

Correlations Between MA, IQ, or CA and Each of the Count Scores for Experimentals with Equal Original Ability

	Unassisted High (N = 14) [9 - 19]		Unassisted Correct Terms to 40 (N = 12) [10 -26.5]		Unassisted Strings of Four (N = 14) [2 - 2.55]		Assisted Correct Terms to 40 (N = 12) [10 - 29.5]		Assisted Strings of Four (N = 14) [2 - 6]	
	Post 1	Post 2	Post 1	Post 2	Post 1	Post 2	Post 1	Post 2	Post 1	Post 2
MA	0.39	0.49	0.09	-0.27	0.42	0.14	-0.30	-0.55	0.28	0.19
	0.16	0.07	0.79	0.40	0.22	0.69	0.34	0.06	0.40	0.57
IQ	0.40	0.43	0.08	-0.43	0.095	-0.25	-0.06	-0.24	0.11	-0.13
	0.16	0.13	0.81	0.17	0.79	0.55	0.85	0.45	0.74	0.71
CA	0.09	-0.06	0.19	0.20	0.38	0.44	-0.25	-0.39	0.09	0.28
	0.36	0.83	0.54	0.54	0.28	0.20	0.43	0.21	0.78	0.40

Note. For each count score, the number of subjects included in the analysis is indicated in parentheses. The range in the pretest scores is indicated in brackets. Pretest scores in the upper range that may have been subject to a ceiling effect were not included.

Table 6

A Comparison of Mean Gain Counting Scores for Experimentals with MA Less Than and More Than 4 1/2

Group	Unassisted High		Unassisted Correct Terms to 40		Unassisted Strings of Four		Assisted Correct Terms to 40		Assisted Strings of Four	
	Post 1	Post 2	Post 1	Post 2	Post 1	Post 2	Post 1	Post 2	Post 1	Post 2
MA<4.5	1.9	5.4 (N=4)	10.3	9.3 (N=5)	1.4	1.9 (N=4)	10.7	9.5 (N=4)	4.0	2.1 (N=4)
MA>4.5	10.1	10.8 (N=10)	7.8	7.3 (N=7)	2.2	1.7 (N=6)	12.2	9.3 (N=8)	1.9	1.9 (N=7)

Note. None of the mean differences were statistically significant (Mann-Whitney test).